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Surface combatant readiness to confront a sea control navy

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MONTEREY, CALIFORNIA

THESIS

SURFACE COMBATANT READINESS TO CONFRONT A SEA CONTROL NAVY

by

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September 2008

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This thesis proposes to correct the shortfalls in the US Surface Combatants ability to counter a Sea-Control Navy. The concept counters this threat using unmanned aerial systems, decoys, and a layered defense. We analyze the performance with a Filtering Model of Salvo Warfare that is an extension of the Hughes Salvo Equations. The model incorporates the diluting effect of decoys upon enemy salvos and accounts for the historical reality of leakers. We conclude that in the absence of air support provided by US Carriers the warships that will have to reestablish sea control will be Arleigh Burke Destroyers based on current force composition. In summary, the thesis illustrates serious combat shortfalls in Surface Warfare of DDGs against a numerically superior Chinese Surface Action Group and proposes a reasonable solution of three key upgrades. The first upgrade is a long range TASM-like missile to correct the current DDG's lack of long range offensive missiles. The next two upgrades are both unmanned aerial systems. The Global Hawk maritime variant would provide offensive targeting data to surface combatants allowing for a successful first strike. The Fire Scout would provide local airborne early warning to allow for timely launches of decoys and defensive missiles.

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SURFACE COMBATANT READINESS TO CONFRONT A SEA CONTROL NAVY

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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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This thesis proposes to correct the shortfalls in the U.S. Surface Combatants ability to counter a Sea-Control Navy. The concept counters this threat using unmanned aerial systems, decoys, and a layered defense. We analyze the performance with a Filtering Model of Salvo Warfare that is an extension of the Hughes Salvo Equations. The model incorporates the diluting effect of decoys upon enemy salvos and accounts for the historical reality of leakers. We conclude that in the absence of air support provided by U.S. Carriers the warships that will have to reestablish sea control will be Arleigh Burke Destroyers based on current force composition. In summary, the thesis illustrates serious combat shortfalls in Surface Warfare of DDGs against a numerically superior Chinese Surface Action Group and proposes a reasonable solution of three key upgrades. The first upgrade is a long range TASM-like missile to correct the current DDG's lack of long range offensive missiles. The next two upgrades are both unmanned aerial systems. The Global Hawk maritime variant would provide offensive targeting data to surface combatants allowing for a successful first strike. The Fire Scout would provide local airborne early warning to allow for timely launches of decoys and defensive missiles.

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THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made within the available time to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification and validation is at the risk of the user.

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EXECUTIVE SUMMARY

This thesis addresses surface warfare shortfalls of U.S. Navy Destroyers when countering a Chinese Sea-Control Navy in the absence of carrier based strike aircraft. The analysis was conducted using a new Filtering Model, an extension of the Hughes Salvo Equations that incorporates decoys and leakers. Using the Filtering Model, we analyzed five scenarios. In the first scenario current force composition is compared in the form of a three DDG Surface Action Group confronting a six ship PLA Navy Surface Action Group. In the second, we add "leakers" (ASCMs that penetrate SAM defense). In the third scenario a proposed Tomahawk Anti-Ship Missile (TASM) with the added capability of persistent long range ISR is shown. In the fourth scenario, we add enhanced defensive capability with local airborne early warning (AEW) and the use of decoys. In the fifth scenario the DDGs with all three combined upgrades are compared against the Chinese SAG.

The results show that four DDGs can reach parity with a Chinese SAG of three Luyang II and three Sovremenny Destroyers with three key upgrades. The first upgrade is a long range TASM-like missile to correct the current DDG's lack of long range offensive missiles. The next two upgrades are both unmanned aerial systems. The Global Hawk maritime variant would provide offensive targeting data to surface combatants allowing for a successful first strike. The Fire Scout would provide local airborne early warning to allow for timely launches of decoys and defensive missiles.

With these additions and based on the results we propose a concept of operations to allow a U.S. SAG to compete with a Chinese SAG for sea control. Results show that a 2:3 ratio is required to reach parity using upgraded DDGs. Four DDGs each operating three Fire Scouts would allow decoy systems to decoy and eliminate a significant number of attacking missiles. This would greatly reduce the number left to engage using point defense. Two Global Hawks operating around 80 to 100 nautical miles away would provide enough ISR to allow for the U.S. SAG to conduct a first attack. The TASM would then be employed to eliminate enemy surface combatants. The results stress the importance of offensive missile range and defensively launching decoys.

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I. INTRODUCTION

A. BACKGROUND

The U.S. Navy has since World War II relied upon the presumption of carrier dominance to provide persistent Air Support for surface combatants. This has allowed the American surface combatants to become better suited as land attack platforms than for surface warfare. "The Navy because of its Sea Sanctuary has not been shot at much and has had less motivation to change." (Hughes 2006) The sea sanctuary has been guaranteed to U.S. warships by U.S. carriers because of their immense capabilities and more importantly after the Cold War there has not been a peer competitor to challenge them for sea control.

There has been a great deal of attention paid to surface warfare in littoral waters with the primary threat coming from numerous missile-laden vessels that move at great speed. This has resulted in heated debates over platform types and the numbers required for these specialized missions against a potent but smaller nation adversary. Of course, to get to the littorals access must be first established by controlling the blue water. This is a mission that U.S .Carriers have accomplished successfully.

Efforts to circumvent the Carrier's dominance have developed in the form of an "Assassin's Mace" weapon designed to foul the flight deck which would provide a mission kill essentially placing that platform out of action. China has demonstrated that they have the capability to shadow U.S. carriers with submarines capable of launching such a weapon at close range. Therefore, the Carrier is placed out of action from a mission kill or it is cautiously pulled far enough away to minimize this threat creating an end result that is essentially the same; ceded battle-space. Modern sea-denial or anti-access efforts carried out in the open ocean by any nation refreshes the necessity of sea control by one navy over another that seeks to restrict access to trade routes or resources. This thesis explores a scenario where disputes over natural resources with China could draw the U.S. Navy into a mission area that it is unaccustomed to and unprepared for.

The problem is that sea control must be regained against a peer competitor such as China that has roughly equivalent surface combatants with longer range offensive missiles. The U.S. Navy has not pursued offensive missile technology for its surface combatants to the extent that other countries have because of the U.S. reliance upon carrier air dominance. When a U.S. surface action group's surface warfare capabilities are assessed against China's without carrier air coverage the disparities are glaring.

Currently there are numerous anti-ship cruise missiles (ASCMs) designed specifically to defeat the Aegis weapon system both in quantity and capability. The U.S. Navy fleet size is dwindling as an unfortunate antithesis to the importance of numerical superiority in surface warfare. The prevalence of so many cost effective ASCMs makes our numerical disadvantage against enemy fleets even more critical.

B. SCENARIO

Southwest of the Spratley Islands there are many oil and natural gas resources found in the seabed that have been claimed by a panoply of countries including Malaysia, Philippines, Indonesia, Vietnam, and China. The increasing importance of global energy resources increases tensions among countries vying for ownership. This scenario could quite easily take place off the coast of Japan or many other countries but the underlying point is that scarce resources offshore will require a naval force to demonstrate control. This region is routinely hit by major typhoons, heavy monsoons, and devastating tsunamis caused by earthquakes. These volatile seas also host a considerable threat of piracy lured by the steady stream of merchant vessels that congest and complicate the battle space.

In the scenario a severe natural disaster brings the Chinese to the aid of Pacific rim neighbors. China then uses that momentary advantage to seize control of the seas southwest of the Spratley Islands. The U.S. is forced to intercede on behalf of the Philippines, Vietnam, and Indonesia to contest China's assertion of ownership. China threatens retaliation and openly directs available submarines to shadow and harass the two U.S. carriers in the area. The result is that the U.S. must send in a surface action group to counter the Chinese force leading to various missile exchange combinations.

C. PURPOSE

The purpose of this thesis is to demonstrate current shortfalls in surface warfare of a surface action group against a comparable Chinese force. We are using a Filtering Model of Salvo Warfare based upon Hughes Salvo Equations to demonstrate the benefits of decoys and take into account the historical reality of leakers. We will use these results to recommend a concept of operation for this mission with current and near term capabilities.

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II. SALVO MODEL

A. HUGHES SALVO MODEL

1. Background

Hughes salvo model (Hughes 2000) is a useful analytic tool for assessing the crucial capabilities of surface combatants. The model provides a method to analyze the important trade-offs between defensive power, offensive power, staying power, and numbers of units. Analysis of these principle factors has allowed these equations to be used in comparing two opposing forces at sea to explore how they match up. The equations can be used to show the Fractional Exchange Rate (FER) of one force to another based upon the number of incoming missiles that continue on to point defense after having been engaged by defensive missiles of the opposing force. The simplicity of the equations contradicts the complexity of the interactions between the principle factors.

2. Assumptions

The salvo model assumes that a salvo is uniformly distributed across all defending units. As a mathematical artifact the model assumes a linear transition within offensive power, defensive power, and staying power. Another assumption is that once parity is reached any additional shots are unable to be engaged and will saturate the defender. In the equations fractions will result but that does not imply a fractional hit or softkill. Each force is also assumed to be homogenous.

3. Definitions

a. Force

A group of naval warships that fight against an enemy group.

b. Unit

An individual warship in a force.

c. Salvo

A number of shots fired from a force in a discrete time period.

d. Engagement

A number of shots fired in the same salvo.

e. Offensive Power

The maximum number of shots that can be fired by one unit in one Salvo at the opposing force.

f. Defensive Power

The maximum number of attacking shots that can be killed by a unit.

g. Staying Power

The number of shots a unit can take before being placed out of action.

h. Scouting Effectiveness

A number between zero and one that describes the potential for one force to target another. At one, the attacker can fire with perfect targeting information. At zero the attacker does not know where the enemy unit is located and cannot attack.

i. Defensive Alertness

A number between zero and one that describes the potential for one force to defend against another. At one, the defender is fully manned and ready to defend the ship to the maximum capability. At zero the ship has no idea that an attack will take place or have the capability of dealing with an attack should it occur.

j. Heavy Defense

A situation in which a defending force has more defensive missiles to shoot at a salvo than there are shots in the salvo. In this case a force can shoot at a salvo again using these extra missiles for a second engagement.

k. Heavy Offense

A situation in which an attacking force fires more shots than the defending force can shoot down in one salvo.

l. Parity

A situation in which the number of attacking shots equals the number of defending shots.

4. Homogenous Equations

$\Delta A = ((\sigma b*\beta*B)-(\tau a*a3*A))/a1$

$\Delta B = ((\sigma a*\alpha*A)-(\tau b*b3*B))/b1$

Where,

A = number of units in force A

B = number of units in force B

α = number of shots fired by each A unit

β = number of shots fired by each B unit

σa = Scouting Effectiveness of A force

σb = Scouting Effectiveness of B force

τa = Defensive Alertness of A force

τb = Defensive Alertness of B force

a1 = number of hits required to place one A unit out of action

b1 = number of hits required to place one B unit out of action

a3 = number of missiles that can be shot down by each A per salvo

b3 = number of missiles that can be shot down by each B per salvo

B. FILTERING MODEL

1. Background

Hughes salvo equations are an elegantly simple method of comparing surface combatants. The intent of the filtering model is to allow these same equations to describe a greater amount of interaction during a theoretical tactical exchange between two forces. The concept of leakers, known for quite some time, has been shown as a historical reality (Schulte 1994). The salvo equations were developed to compare warship attributes, not to determine battle outcomes so leakers were relegated as a topic for tactical discussion. We wanted to incorporate their effect into a comparison of two forces to determine how an additional percentage of leakage would affect the exchange. Leakers are a result of imperfect knowledge or in other words are due to fire control system ambiguity and not the number of missiles a ship fires in defense. Another concept we wanted to demonstrate within the equations is the ability for decoys to dilute an enemy missile raid. Essentially, we began adding layers to the original salvo exchange so the model resembled a filter where at every layer more enemy missiles could be mitigated. In order to focus on the effect of leakers and decoys, we did not add layers for chaff or point defense. Just like the salvo equations there are three situations that develop for each force. They encounter a strong offense, they have a strong defense or there is parity. In the case of heavy defense there are more missiles left to shoot than there are offensive missiles attacking. This case is dealt with by allowing the force to have a second engagement on that same salvo. The salvo equations result in a Fractional Exchange Ratio between forces. The filtering model looks at the number of missiles inbound to a force and the effect decoys and leakers have upon that number. This shows the ability of systems to mitigate attacking missiles by calculating the number of missiles that continue to the next layer at each step. The equations used to calculate the number of missiles is conditional upon the situation of strong offense, strong defense, or parity.

2. Assumptions

The filtering model has a few more assumptions in addition to the ones described for the salvo equations. The first assumption is that a percentage of leakage will occur in a salvo based upon the number of attacking missiles. The second assumption is that the percentage of leakers that slip through a defensive engagement is constant regardless of engagement range. The last assumption is that in a heavy defense situation the force with missiles left to fire will get a second engagement within the same salvo. This is despite the possibility that based on missile kinematics there might not be time for a second engagement.

3. Definitions

a. Leaker

A missile that avoids being shot down by a defending unit because of the ambiguity of the fire control system at targeting the shot.

4. Equations with Conditions

Initial SAM Engagement:

$Wa = (\sigma b*\beta*B)-(\tau a*a3*A)$

$Wb = (\sigma a*\alpha*A)-(\tau b*b3*B)$

Initial Engagement plus Leakers:

$Xa = \sigma b*\beta*B*\lambda a$, Strong A Defense and Parity

$Xa = Wa + (\sigma b*\beta*B*\lambda a)$, Strong B Offense

$Xb = \sigma a*\alpha*A*\lambda b$, Strong B Defense and Parity

$Xb = \sigma a*\alpha*A*\lambda b$, Strong A Offense

Decoy Dilution

$Ya = A * (Xa/ (\delta a + A))$, Number of Decoys > 0

$Ya = Xa$, Number of Decoys = 0

$Yb = B * (Xb/ (\delta b + B))$, Number of Decoys > 0

$Yb = Xb$, Number of Decoys = 0

Second SAM Engagement:

$Za = Ya*\lambda a$, Strong B Offense and Parity

$Za = (Ya - |Wa|) + (Ya*\lambda a)$, Strong A Defense

$Zb = Yb*\lambda b$, Strong A Offense and Parity

$Zb = (Yb - |Wb|) + (Yb*\lambda b)$, Strong B Defense

Where,

Wa = number of B missiles that continue inbound after first engagement

Wb = number of A missiles that continue inbound after first engagement

Xa = number of B missiles that continue after 1st engagement plus leakers

Xb = number of A missiles that continue after 1st engagement plus leakers

Ya = number of B missiles that continue after decoy dilution

Yb = number of A missiles that continue after decoy dilution

Za = number of B missiles that continue to point defense

Zb = number of A missiles that continue to point defense

A = number of units in force A

B = number of units in force B

α = number of shots fired by each A unit

β = number of shots fired by each B unit

a3 = number of missiles that can be shot down by each A per salvo

b3 = number of missiles that can be shot down by each B per salvo

δa = number of decoys used by A force

δb = number of decoys used by B force

σa = Scouting Effectiveness of A force

σb = Scouting Effectiveness of B force

τa = Defensive Alertness of A force

τb = Defensive Alertness of B force

λa = Percentage of Leakers that slip through A defense

λb = Percentage of Leakers that slip through B defense

5. Model Setup for Analysis

This thesis uses a *Microsoft® Excel* spreadsheet as the calculating device to implement the filtering model. This was used because of the simplicity of the calculations, the ease of programming, and the ability to deal with conditional situations. The model was meant to provide quick analysis using simple arithmetic. In fleet use this model could be programmed and run with very little training.

The model allows the user to input different combinations of ship characteristics for two forces; A and B. Each force will have four layers of calculations to determine the total number of inbound missiles. The initial exchange is based upon Hughes salvo equations, whereby the number of attacking missiles is checked against the number of missiles fired defensively. The result of this exchange is the number of attacking missiles that continue after the first engagement. The salvo model takes this result and divides it by the number of hits to place one ship out of action to get the change in the number of units. The filter model continues to the next layer with this initial number of inbound attacking missiles for each force. This number indicates whether the exchange has heavy offense, a strong defense, or if the exchange has reached parity.

The next layer of calculations adds in a percentage of leakers based on the inputs. Throughout our analysis we used .3 (30%) for both forces. Depending on which of the three cases the number of leakers will be calculated based on the number of attacking missiles and then added to the results from the initial exchange. This will be the number of attacking missiles that each force must shoot down.

After the addition of leakers to the initial exchange numbers the ability for decoys to dilute attacking missiles will be assessed. A defending force will most likely be unable to determine which missile will be decoyed away so they will have to shoot down all inbound missiles. The calculations for decoys diluting attacking missiles away from a defending force have been based upon a simple premise; each decoy will be just as effective at drawing a missile as a ship. This means that if we have one decoy and one ship 50% of the missiles will be drawn to a decoy and 50% will continue to the ship. With two decoys this percentage decreases to 33% for each decoy and ship. (Figure 1) If there are no decoys operating for a force then the number of inbound missiles is the same as the previous layer. The number of inbound missiles is then evenly allocated across decoys and ships to yield a number of missiles that continues to each ship after decoy dilution.

In a heavy defense situation the number of defensive missiles is far higher than the number of attacking missiles. The model accounts for this disparity by allowing a second engagement upon the same salvo after the decoys have diluted the number of inbound missiles. This calculation checks the number of attacking missiles against the number of leftover defensive missiles and then adds in the same percentage of leakers as calculated in the second layer.

The resulting number is the number of attacking missiles that continue on to chaff and point defense for the entire force. It does not provide any information about how many will hit their intended targets. Additional layers of chaff and point defense have not been added into our calculations. To incorporate chaff and point defense their effects can be added as a final layer of each ship's defense. The layout shown in Figure 2 is used to show the results of our engagements. The model is sequential using the inputs at the top to fill in the required information at each subsequent step starting with W and ending at Z. The additional layers of chaff and point defense would be added after Z.

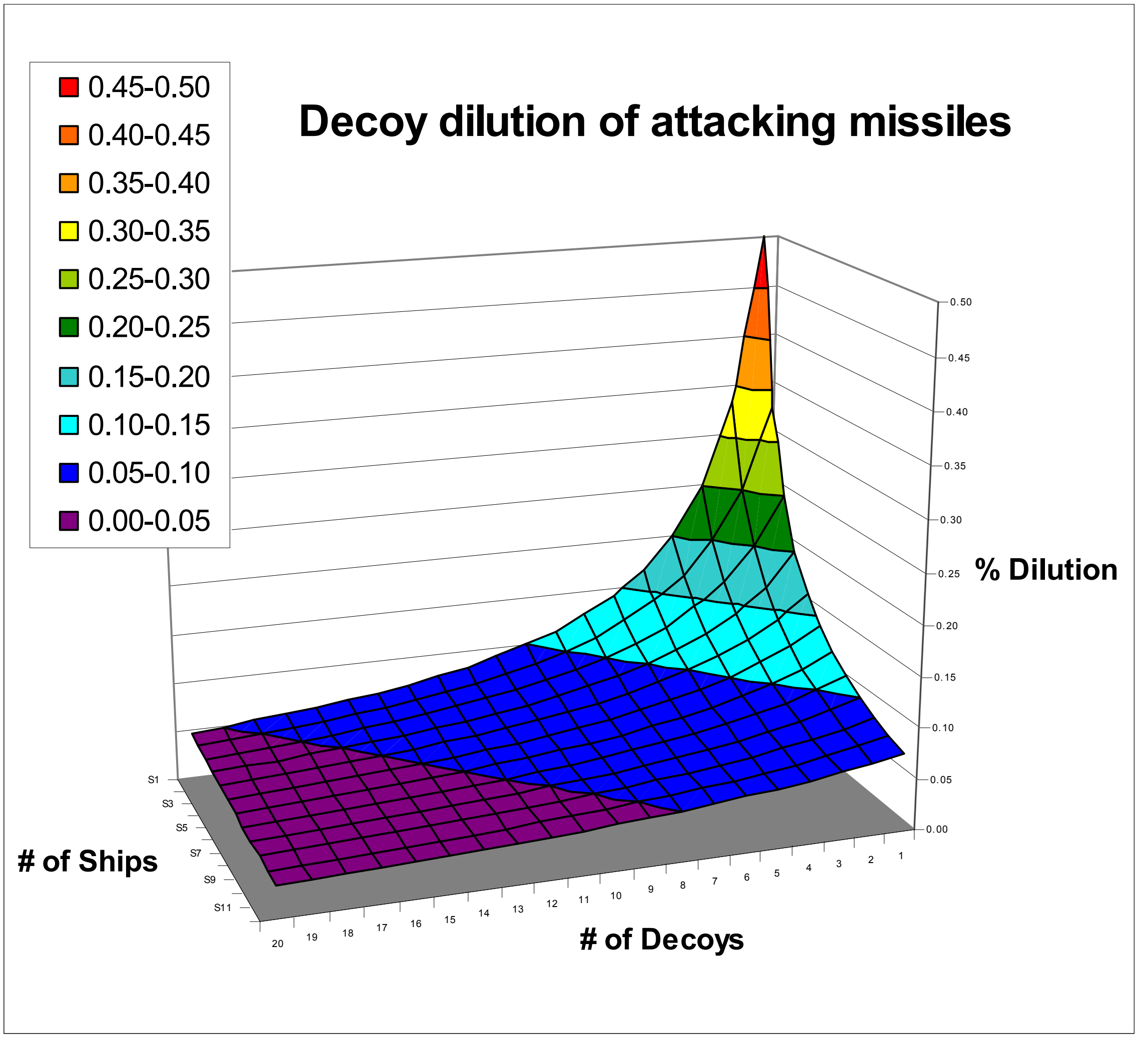

Figure 1. Decoy dilution of attacking missiles

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Filtering Model using Hughes Salvo Equations

Basic Inputs		
# Units in Force A	**A**	3
# Units in Force B	**B**	6
# Shots fired by each A	**α**	8
# Shots fired by each B	**β**	8
# hits to place 1 A OOA	**a1**	2
# hits to place 1 B OOA	**b1**	2
# msls destryd by each A	**a3**	8
# msls destryd by each B	**b3**	8

Mod Inputs		
% leakers through A def.	**λa**	0.3
% leakers through B def.	**λb**	0.3
Scouting eff. Of A	**σa**	1
Scouting eff. Of B	**σb**	1
Def. Alertness of A	**τa**	1
Def. Alertness of B	**τb**	1
# of Decoys used by A	**δa**	6
# of Decoys used by B	**δb**	0

First SAM Engagement

# A Missiles fired Defensively	**a3*A**	24
# Inbound B Missiles	**β*B**	48

Wa = ((σb*β*B) - (τa*a3*A))

W

# B Missiles that continue after 1st Eng.	**Wa**	24

# B Missiles fired Defensively	**b3*B**	48
# Inbound A Missiles	**α*A**	24

Wb = ((σa*α*A) - (τb*b3*B))

# A Missiles that continue after 1st Eng.	**Wb**	-24

STRONG B OFFENSE

Strong A Defense
Wa is negative:
Xa = σb*β*(λa)*B

Parity between A Defense & B Offense
Wa is equal to zero:
Xa = σb*β*(λa)*B

Strong B Offense
Wa is positive:
Xa = Wa+ (σb*β*(λa)*B)

X

plus # of B Leakers + 14.4

# B Missiles that continue in	**Xa**	38.4

STRONG B DEFENSE

Strong B Defense
Wb is negative:
Xb = σa*α*(λb)*A

Parity between B Defense & A Offense
Wb equals zero:
Xb = σa*α*(λb)*A

Strong A Offense
Wb is positive:
Xb = Wb+ (σa*α*(λb)*A)

plus # of A Leakers + 7.2

# A Missiles that continue in	**Xb**	7.2

If # A decoys = 0, then Ya = Xa

If # A decoys > 0, then Ya = #A *(Xa/(#A decoys+ #A))

Y

minus # diluted by A's decoys - 25.60

# B Missiles that continue in	**Ya**	12.80

If # B decoys = 0, then Yb = Xb

If # B decoys > 0, then Yb = #B *(Xb/(#B decoys+ #B))

minus # diluted by B's decoys - 0.00

# A Missiles that continue in	**Yb**	7.20

If Wa is negative, there are missiles left to shoot, which allows A a second engagement on the same salvo

Can A engage again?	**(Y/N)**	NO

If Wb is negative, there are missiles left to shoot, which allows B a second engagement on the same salvo

Can B engage again?	**(Y/N)**	YES

Second SAM Engagement

If |Wa| >= Ya, then Za = Ya*λa

If |Wa| < Ya, then Za = (Ya-|Wa|) + (Ya*λa)

Z

# B Missiles that continue to point defense	**Za**	12.80

If |Wb| >= Yb, then Zb = Yb*λb

If |Wb| < Yb, then Zb = (Yb-|Wb|) + (Yb*λb)

# A Missiles that continue to point defense	**Zb**	2.16

Figure 2. Filter Model Implementation using Microsoft Excel

III. SCENARIO ANALYSIS

A. SCENARIO BASE CASE

1. Background

This scenario involves a U.S. Surface Action Group (SAG) that has been tasked to regain sea control of an open ocean area patrolled by a Chinese SAG. The U.S. Order of Battle contains 3 Arleigh Burke DDGs while the Chinese have 3 Luyang II DDGs and 3 Sovremenny DDGs. We will assume that the Chinese SAG will be expecting the U.S. SAG based on American political rhetoric so the scenario begins with both forces in Condition 1 (General Quarters) actively seeking to find and attack the other within a 600x600nm area. The advantage will be with the force who finds the other first and attacks first to minimize the possibility for a counter-attack while putting as many enemy ships as possible out of action (OOA). Both forces have the expectation of imminent attack and will therefore be at the highest readiness level to fight (implying that they will be radiating using shipboard radars). The U.S. SAG will not be able to “sneak in” by placing the SPY radar in low power or standby because of the imminent threat of attack. The strength of the Aegis System is in the SPY radar data. This will require SPY to be placed in Full Power 360 degrees.

The importance of the U.S. forces radiating will become apparent when we introduce additional factors that rely upon homogeneous force configuration. Each Luyang II will be paired with one Sovremenny Destroyer as an operating pair to maximize the capability of the Sovremenny’s offensive missiles while pairing it with the better air defenses of the Luyang II.

US SAG Order of Battle	
Arleigh Burke Flight IIA Destroyer	
SM-2 Standard Missile (SAM)	20
SM-3 Standard Missile (BMD)	-
Tomahawk Land Attack Missile	-
Mk 45 5" Gun	1

Chinese SAG Order of Battle	
Type 052C Luyang II Destroyer	
YJ-62 Anti-Ship Missile	8
HQ-9 (SAM) Air Defense	48
100mm Gun	1
Close In Weapon System	2
Project 956 Sovremenny Destroyer	
Sunburn Anti-Ship Missile	8
Gadfly (SAM) Air Defense	48
130mm Gun	1
Kashtun Point Defense System	2

Force A: US SAG		
# Units in Force A	**A**	3
# Shots fired by each A	**α**	0
# hits to place 1 A OOA	**a1**	2
# msls destryd by each A	**a3**	8
Scouting eff. Of A	**σa**	1
Def. Alertness of A	**τa**	1
% leakers through A def.	**λa**	0.3
# of Decoys used by A	**δa**	0

Force B: Chinese SAG		
# Units in Force B	**B**	6
# Shots fired by each B	**β**	8
# hits to place 1 B OOA	**b1**	2
# msls destryd by each B	**b3**	8
Scouting eff. Of B	**σb**	1
Def. Alertness of B	**τb**	1
% leakers through B def.	**λb**	0.3
# of Decoys used by B	**δb**	0

Table 1. Presumed U.S. and Chinese Order of Battle and inputs to the filter model

2. Introduction

There are three possible cases to be examined. U.S. (A force) attacks first, China (B force) attacks first or there is a simultaneous exchange. By changing σa from 1 to 0 we can effectively reduced the scouting effectiveness of A preventing them from targeting the B force and similarly for σb. This slight alteration can be used to show the consequences of one force being outside the weapons range of another. The Harpoon is currently the only offensive weapon that is used by U.S. surface combatants as a long range anti-ship cruise missile. Unfortunately, Flight IIA Destroyers do not have this weapon and therefore cannot attack using ASCMs. If the Chinese SAG is outside the maximum range of this weapon then σa becomes zero and no damage can be inflicted upon the Chinese SAG. Missile range is fundamental for attacking first, if at all, during a battle. The numbers have been omitted for SM-3 ballistic defense missiles and Tomahawk land attack missiles because they do not directly affect the analysis and for classification purposes. Also, on all the surface combatants guns do not affect the results because of their short range. It is conceivable if both sides ran out of missiles that gun batteries would be employed offensively, but that rare case is not addressed here. We placed the guns in the realm of point defense, which is not analyzed in this thesis.

B. SCENARIO WITH LEAKERS

1 Assumptions

In the analysis we will treat the Luyang and the Sovremenny as the same homogenous force with the same numbers of offensive and air defense weapons. As mentioned, we will use Flight IIA Destroyers, so Harpoons will not be available. However, in this initial case we have added them to show what their contribution would be. The number of leakers used in these scenarios is set at 30% of the attacking missiles.

US SAG Order of Battle	
Arleigh Burke Flight IIA Destroyer	
Harpoon Anti Ship Missile	4
SM-2 Standard Missile (SAM)	20
SM-3 Standard Missile (BMD)	-
Tomahawk Land Attack Missile	-
Mk 45 5" Gun	1

Chinese SAG Order of Battle	
Type 052C Luyang II Destroyer	
YJ-62 Anti-Ship Missile	8
HQ-9 (SAM) Air Defense	48
100mm Gun	1
Close In Weapon System	2
Project 956 Sovremenny Destroyer	
Sunburn Anti-Ship Missile	8
Gadfly (SAM) Air Defense	48
130mm Gun	1
Kashtun Point Defense System	2

Force A: US SAG		
# Units in Force A	A	3
# Shots fired by each A	α	4
# hits to place 1 A OOA	a1	2
# msls destryd by each A	a3	8
Scouting eff. Of A	σa	0
Def. Alertness of A	τa	1
% leakers through A def.	λa	0.3
# of Decoys used by A	δa	0

Force B: Chinese SAG		
# Units in Force B	B	6
# Shots fired by each B	β	8
# hits to place 1 B OOA	b1	2
# msls destryd by each B	b3	8
Scouting eff. Of B	σb	1
Def. Alertness of B	τb	1
% leakers through B def.	λb	0.3
# of Decoys used by B	δb	0

Table 2. Base case with σa disadvantage

2. Application

In this scenario the Chinese SAG attacks without a response from the U.S. There are two possibilities for this outcome. Either the U.S. SAG is unaware of the imminent threat and is completely surprised or the Chinese SAG attacks from outside the range of U.S. harpoons. We are examining the case that the U.S. is aware of the imminent threat but is unable to respond based on the short range of their Harpoon missiles. The ability for the Chinese SAG to attack outside of U.S. offensive range essentially nullifies the Harpoon missiles regardless of how many the DDG carries. Leakers add to the number of missiles that get through to U.S. point defense additively. In this case even without leakers the Chinese attack would be overwhelming based on their numerical advantage and offensive missile range.

The Filter model applied in Figure 3 shows a mathematical artifact embedded within the spreadsheet calculations. In the right hand column the number of B force's missiles fired defensively and the number of inbound A force's missiles is listed. The number below that is the number of A missiles that continue after the first engagement, named Wb. At this step, the model incorporates σa and τb into the equations as described in Equations with Conditions. The next step calculates Xb as shown in Figure 2. If Xb is equal to zero then that indicates that σa is also equal to zero and similarly for Xa. When σa or σb are equal to zero leakage does not occur. Figure 4 and Figure 5 also show this mathematical artifact occurring.

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Filtering Model using Hughes Salvo Equations

Basic Inputs		
# Units in Force A	A	3
# Units in Force B	B	6
# Shots fired by each A	α	4
# Shots fired by each B	β	8
# hits to place 1 A OOA	a1	2
# hits to place 1 B OOA	b1	2
# msls destryd by each A	a3	8
# msls destryd by each B	b3	8

Mod Inputs		
% leakers through A def.	λa	0.3
% leakers through B def.	λb	0.3
Scouting eff. Of A	σa	0
Scouting eff. Of B	σb	1
Def. Alertness of A	τa	1
Def. Alertness of B	τb	1
# of Decoys used by A	δa	0
# of Decoys used by B	δb	0

First SAM Engagement

	# A Missiles fired Defensively	a3*A	24	# B Missiles fired Defensively	b3*B	48
	# Inbound B Missiles	β*B	48	# Inbound A Missiles	α*A	12
W	# B Missiles that continue after 1st Eng.	Wa	24	# A Missiles that continue after 1st Eng.	Wb	-48
	STRONG B OFFENSE			STRONG B DEFENSE		
	plus # of B Leakers		+ 14.4	plus # of A Leakers		+ 0
X	# B Missiles that continue in	Xa	38.4	# A Missiles that continue in	Xb	0
	minus # diluted by A's decoys		- 0.00	minus # diluted by B's decoys		- 0.00
Y	# B Missiles that continue in	Ya	38.40	# A Missiles that continue in	Yb	0.00
	Can A engage again?	(Y/N)	NO	Can B engage again?	(Y/N)	YES

Second SAM Engagement

Z	# B Missiles that continue to point defense	Za	38.40	# A Missiles that continue to point defense	Zb	0.00

Figure 3. Filter model results for base case with σa disadvantage

C. SCENARIO WITH TASM AND LONG RANGE ISR

1. Assumptions

In the place of Harpoon we will use a missile with a long range able to attack hundreds of miles away, basically a Tomahawk with the ability to attack surface targets. Here, we will refer to this missile as the Tomahawk Anti-Ship Missile (TASM). Without specifying an exact range requirement we will describe this missile as having a range in excess of the YJ-62 and Sunburn missiles used by the Chinese. In addition to the TASM the U.S. will need the capability of long range Intelligence, Surveillance, and Reconnaissance (ISR) to provide the TASM with over-the-horizon targeting (OTH-T). These two upgrades will be described later in more detail.

US SAG Order of Battle	
Arleigh Burke Flight IIA Destroyer	
Tomahawk Anti-Ship Missile	10
SM-2 Standard Missile (SAM)	20
SM-3 Standard Missile (BMD)	-
Tomahawk Land Attack Missile	-
Mk 45 5" Gun	1
Long Range ISR Capability	

Chinese SAG Order of Battle	
Type 052C Luyang II Destroyer	
YJ-62 Anti-Ship Missile	8
HQ-9 (SAM) Air Defense	48
100mm Gun	1
Close In Weapon System	2
Project 956 Sovremenny Destroyer	
Sunburn Anti-Ship Missile	8
Gadfly (SAM) Air Defense	48
130mm Gun	1
Kashtun Point Defense System	2

Force A: US SAG		
# Units in Force A	A	3
# Shots fired by each A	α	10
# hits to place 1 A OOA	a1	2
# msls destryd by each A	a3	8
Scouting eff. Of A	σa	1
Def. Alertness of A	τa	1
% leakers through A def.	λa	0.3
# of Decoys used by A	δa	0

Force B: Chinese SAG		
# Units in Force B	B	6
# Shots fired by each B	β	8
# hits to place 1 B OOA	b1	2
# msls destryd by each B	b3	8
Scouting eff. Of B	σb	0
Def. Alertness of B	τb	1
% leakers through B def.	λb	0.3
# of Decoys used by B	δb	0

Table 3. U.S. SAG upgraded with TASM and long range ISR

2. Application

The results of upgrading the U.S. SAG with TASM's and long range ISR are predictable. The Chinese SAG has σb reduced to zero because of the longer range of the TASM. If we examined a situation in which both forces were within attacking range of one another but the U.S. force attacked first the results would be the same. Attacking first is a significant advantage as it can significantly reduce the enemy's capability to counterattack. In this case both sides have negative Wa and Wb numbers. This indicates that this is a heavy defense situation where the U.S. and the Chinese have more defensive missiles than there are attacking missiles. The difference becomes apparent when leakers are added in and the American salvo must be engaged a second time by the Chinese.

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Filtering Model using Hughes Salvo Equations

Basic Inputs		
# Units in Force A	A	3
# Units in Force B	B	6
# Shots fired by each A	α	10
# Shots fired by each B	β	8
# hits to place 1 A OOA	a1	2
# hits to place 1 B OOA	b1	2
# msls destryd by each A	a3	8
# msls destryd by each B	b3	8

Mod Inputs		
% leakers through A def.	λa	0.3
% leakers through B def.	λb	0.3
Scouting eff. Of A	σa	1
Scouting eff. Of B	σb	0
Def. Alertness of A	τa	1
Def. Alertness of B	τb	1
# of Decoys used by A	δa	0
# of Decoys used by B	δb	0

First SAM Engagement						
	# A Missiles fired Defensively	a3*A	24	# B Missiles fired Defensively	b3*B	48
	# Inbound B Missiles	β*B	48	# Inbound A Missiles	α*A	30
W	# B Missiles that continue after 1st Eng.	Wa	-24	# A Missiles that continue after 1st Eng.	Wb	-18
	STRONG A DEFENSE			STRONG B DEFENSE		
X	plus # of B Leakers	+ 0		plus # of A Leakers	+ 9	
	# B Missiles that continue in	Xa	0	# A Missiles that continue in	Xb	9
Y	minus # diluted by A's decoys	- 0.00		minus # diluted by B's decoys	- 0.00	
	# B Missiles that continue in	Ya	0.00	# A Missiles that continue in	Yb	9.00
	Can A engage again?	(Y/N)	YES	Can B engage again?	(Y/N)	YES
Second SAM Engagement						
Z	# B Missiles that continue to point defense	Za	0.00	# A Missiles that continue to point defense	Zb	2.70

Figure 4. Results with upgrades of TASM and long range ISR for U.S. SAG

D. SCENARIO WITH LOCAL AEW AND DECOYS

1. Assumptions

In this scenario the U.S. will not have any offensive missiles but will be upgraded defensively by a local airborne early warning (AEW) system. This AEW capability will allow decoys to be launched in sufficient time to dilute the number of Chinese missiles that continue on to each U.S. unit. The U.S. SAG launches nine decoys, three from each DDG. The decoys used in this scenario are the MK-53 Nulka systems currently operating on U.S. Destroyers. We will describe their capability by their ability to draw a missile away from a ship. It is assumed that each decoy has an equal probability of drawing an attacking missile as a DDG. (See Figure 1) The number of shots fired by each DDG has been set at 10, but this number is inconsequential because σa is zero.

US SAG Order of Battle	
Arleigh Burke Flight IIA Destroyer	
SM-2 Standard Missile (SAM)	20
SM-3 Standard Missile (BMD)	-
Tomahawk Land Attack Missile	-
Mk 45 5" Gun	1
Local Airborne Early Warning Capability	
3 Decoys launched per Destroyer	

Chinese SAG Order of Battle	
Type 052C Luyang II Destroyer	
YJ-62 Anti-Ship Missile	8
HQ-9 (SAM) Air Defense	48
100mm Gun	1
Close In Weapon System	2
Project 956 Sovremenny Destroyer	
Sunburn Anti-Ship Missile	8
Gadfly (SAM) Air Defense	48
130mm Gun	1
Kashtun Point Defense System	2

Force A: US SAG		
# Units in Force A	**A**	3
# Shots fired by each A	**α**	10
# hits to place 1 A OOA	**a1**	2
# msls destryd by each A	**a3**	8
Scouting eff. Of A	**σa**	0
Def. Alertness of A	**τa**	1
% leakers through A def.	**λa**	0.3
# of Decoys used by A	**δa**	9

Force B: Chinese SAG		
# Units in Force B	**B**	6
# Shots fired by each B	**β**	8
# hits to place 1 B OOA	**b1**	2
# msls destryd by each B	**b3**	8
Scouting eff. Of B	**σb**	1
Def. Alertness of B	**τb**	1
% leakers through B def.	**λb**	0.3
# of Decoys used by B	**δb**	0

Table 4. U.S. SAG upgraded with local AEW and decoys

2. Application

The results from this scenario show the ability for decoys to dilute the number of attacking missiles. Leakage increases the number of missiles by a significant amount as shown in the difference between Wa and Xa. Nine decoys dilute the number of inbound missiles from 38.4 to 9.6 missiles. Even though this is case of a strong Chinese offense, we see that with decoys the U.S. can significantly reduce the number of missiles that must be dealt with using point defense. The model conducts a check after calculating Ya and Yb to see if the SAG can have a second engagement upon the salvo. This depends on whether there are missiles left to shoot for that salvo. So if Wa or Wb is negative, then there are extra missiles that can add a second engagement. In this firing environment it would be difficult to determine if a missile was decoyed away or not so the defending unit would need to engage every missile regardless of whether it was headed for a ship or a decoy.

Interestingly, the results shown in Figure 6 agree with the results of Professor Jeff Kline where he shows that defensive decoys reduce the affect of σb and similarly σa with an inverse square relationship. (Kline 2008) It is possible that both these results are due to the underlying relationship of dilution by decoys shown in Figure 1.

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Filtering Model using Hughes Salvo Equations

Basic Inputs		
# Units in Force A	A	3
# Units in Force B	B	6
# Shots fired by each A	α	10
# Shots fired by each B	β	8
# hits to place 1 A OOA	a1	2
# hits to place 1 B OOA	b1	2
# msls destryd by each A	a3	8
# msls destryd by each B	b3	8

Mod Inputs		
% leakers through A def.	λa	0.3
% leakers through B def.	λb	0.3
Scouting eff. Of A	σa	0
Scouting eff. Of B	σb	1
Def. Alertness of A	τa	1
Def. Alertness of B	τb	1
# of Decoys used by A	δa	9
# of Decoys used by B	δb	0

First SAM Engagement

	# A Missiles fired Defensively	a3*A	24	# B Missiles fired Defensively	b3*B	48
	# Inbound B Missiles	β*B	48	# Inbound A Missiles	α*A	30
W	# B Missiles that continue after 1st Eng.	Wa	24	# A Missiles that continue after 1st Eng.	Wb	-48
	STRONG B OFFENSE			STRONG B DEFENSE		
	plus # of B Leakers	+ 14.4		plus # of A Leakers	+ 0	
X	# B Missiles that continue in	Xa	38.4	# A Missiles that continue in	Xb	0
	minus # diluted by A's decoys	- 28.80		minus # diluted by B's decoys	- 0.00	
Y	# B Missiles that continue in	Ya	9.60	# A Missiles that continue in	Yb	0.00
	Can A engage again?	(Y/N)	NO	Can B engage again?	(Y/N)	YES

Second SAM Engagement

Z	# B Missiles that continue to point defense	Za	9.60	# A Missiles that continue to point defense	Zb	0.00

Figure 5. Results of U.S. SAG upgraded with local AEW and decoys

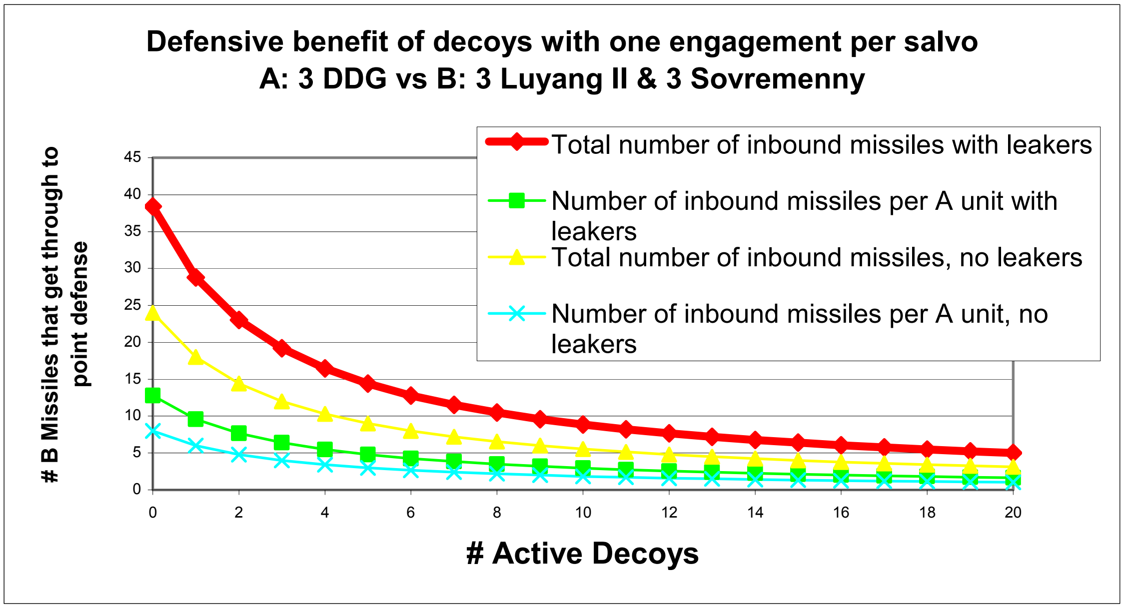

Figure 6. Defensive benefit of decoys

E. SCENARIO WITH COMBINED UPGRADES

1. Assumptions

In this scenario the U.S. Destroyers are upgraded with the offensive and defensive capabilities explored in the previous two scenarios. The range of each force's offensive weapons is crucial. We will assume that both forces are within missile firing range of each other for the interest of discussion. To assess what the result would be of a surprise attack by one force we would only need to look at one side's attack or vice versa.

US SAG Order of Battle	
Arleigh Burke Flight IIA Destroyer	
Tomahawk Anti-Ship Missile	10
SM-2 Standard Missile (SAM)	20
SM-3 Standard Missile (BMD)	-
Tomahawk Land Attack Missile	-
Mk 45 5" Gun	1
Long Range Intel, Surveillance, and Reconnaissance	
Local Airborne Early Warning Capability	
3 Decoys launched per Destroyer	

Chinese SAG Order of Battle	
Type 052C Luyang II Destroyer	
YJ-62 Anti-Ship Missile	8
HQ-9 (SAM) Air Defense	48
100mm Gun	1
Close In Weapon System	2
Project 956 Sovremenny Destroyer	
Sunburn Anti-Ship Missile	8
Gadfly (SAM) Air Defense	48
130mm Gun	1
Kashtun Point Defense System	2

Force A: US SAG		
# Units in Force A	**A**	3
# Shots fired by each A	**α**	10
# hits to place 1 A OOA	**a1**	2
# msls destryd by each A	**a3**	8
Scouting eff. Of A	**σa**	1
Def. Alertness of A	**τa**	1
% leakers through A def.	**λa**	0.3
# of Decoys used by A	**δa**	9

Force B: Chinese SAG		
# Units in Force B	**B**	6
# Shots fired by each B	**β**	8
# hits to place 1 B OOA	**b1**	2
# msls destryd by each B	**b3**	8
Scouting eff. Of B	**σb**	1
Def. Alertness of B	**τb**	1
% leakers through B def.	**λb**	0.3
# of Decoys used by B	**δb**	0

Table 5. U.S. SAG with Combined upgrades

2. Application

As in the previous scenarios the advantage of a first strike is significant. If there is a simultaneous exchange then the Chinese SAG would be expected to fare better with more ships to deal with fewer attacking missiles. The offensive capability of TASM would be reduced if it were not used at the maximum range possible. Targeting information would be very important for both forces. Even when both sides are within each other's attack range this still might be OTH which would require third party targeting or advanced missile capability to find and hit a target. The difference in the number of missiles that each SAG must defeat with point defense is small relative to the number of missiles fired. Leakage is a factor for both forces, but more significantly for the Chinese. The number of missiles that each U.S. unit must defeat using point defense is at least three. As an upper limit one DDG might have to deal with up to ten attacking missiles. Depending on what specific point defense system is used three to ten missiles might be too much for one unit to handle. Three U.S. Destroyers might not be enough to compete with six Chinese Destroyers, but if we add one more DDG of the same specifications to the U.S. SAG we reach parity. Additionally, this relationship holds for multiples of four to six (e.g. 2:3, 4:6, 8:12, 16:24) with three decoys per DDG. The importance of this result is that three decoys costing in the thousands of dollars can mitigate the combat potential of warships costing in the millions or billions of dollars. Also, a U.S. Navy SAG Commander can be armed with the knowledge that to maintain a force advantage his force must number more than 66% of a Chinese SAG with the proposed upgrades.

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Filtering Model using Hughes Salvo Equations

Basic Inputs		
# Units in Force A	A	3
# Units in Force B	B	6
# Shots fired by each A	α	10
# Shots fired by each B	β	8
# hits to place 1 A OOA	a1	2
# hits to place 1 B OOA	b1	2
# msls destryd by each A	a3	8
# msls destryd by each B	b3	8

Mod Inputs		
% leakers through A def.	λa	0.3
% leakers through B def.	λb	0.3
Scouting eff. Of A	σa	1
Scouting eff. Of B	σb	1
Def. Alertness of A	τa	1
Def. Alertness of B	τb	1
# of Decoys used by A	δa	9
# of Decoys used by B	δb	0

First SAM Engagement

	# A Missiles fired Defensively	a3*A	24	# B Missiles fired Defensively	b3*B	48
	# Inbound B Missiles	β*B	48	# Inbound A Missiles	α*A	30
W	# B Missiles that continue after 1st Eng.	Wa	24	# A Missiles that continue after 1st Eng.	Wb	-18
	STRONG B OFFENSE			STRONG B DEFENSE		
	plus # of B Leakers	+ 14.4		plus # of A Leakers	+ 9	
X	# B Missiles that continue in	Xa	38.4	# A Missiles that continue in	Xb	9
	minus # diluted by A's decoys	- 28.80		minus # diluted by B's decoys	- 0.00	
Y	# B Missiles that continue in	Ya	9.60	# A Missiles that continue in	Yb	9.00
	Can A engage again?	(Y/N)	NO	Can B engage again?	(Y/N)	YES

Second SAM Engagement

Z	# B Missiles that continue to point defense	Za	9.60	# A Missiles that continue to point defense	Zb	2.70

Figure 7. Results with combined upgrades, 3 DDGs

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Filtering Model using Hughes Salvo Equations

Basic Inputs		
# Units in Force A	A	4
# Units in Force B	B	6
# Shots fired by each A	α	10
# Shots fired by each B	β	8
# hits to place 1 A OOA	a1	2
# hits to place 1 B OOA	b1	2
# msls destryd by each A	a3	8
# msls destryd by each B	b3	8

Mod Inputs		
% leakers through A def.	λa	0.3
% leakers through B def.	λb	0.3
Scouting eff. Of A	σa	1
Scouting eff. Of B	σb	1
Def. Alertness of A	τa	1
Def. Alertness of B	τb	1
# of Decoys used by A	δa	12
# of Decoys used by B	δb	0

	First SAM Engagement					
	# A Missiles fired Defensively	a3*A	32	# B Missiles fired Defensively	b3*B	48
	# Inbound B Missiles	β*B	48	# Inbound A Missiles	α*A	40
W	# B Missiles that continue after 1st Eng.	Wa	16	# A Missiles that continue after 1st Eng.	Wb	-8
	STRONG B OFFENSE			STRONG B DEFENSE		
	plus # of B Leakers	+ 14.4		plus # of A Leakers	+ 12	
X	# B Missiles that continue in	Xa	30.4	# A Missiles that continue in	Xb	12
	minus # diluted by A's decoys	- 22.80		minus # diluted by B's decoys	- 0.00	
Y	# B Missiles that continue in	Ya	7.60	# A Missiles that continue in	Yb	12.00
	Can A engage again?	(Y/N)	NO	Can B engage again?	(Y/N)	YES
	Second SAM Engagement					
Z	# B Missiles that continue to point defense	Za	7.60	# A Missiles that continue to point defense	Zb	7.60

Figure 8. Results with combined upgrades, 4 DDGs

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V. CONCLUSIONS

A. FILTERING MODEL PERFORMANCE

1. Summary

The Filtering Model of salvo warfare, as an extension of the Hughes Salvo Equations, provides a rapid, transparent method for comparing Surface Action Groups. The results show how significant leakers can be in an ASCM attack, even in heavily defensive scenarios. This model shows the potential for decoys to distract and eliminate a significant number of missiles prior to them reaching point defense systems. Currently the disparity between a U.S. and Chinese Surface Action Group is most apparent in the lack of long range offensive missiles. The results show that defensive missiles such as the SM-2 and the ESSM might prevent defeat but they cannot create victory. Offensive missiles such as the TASM are crucial in the absence of carrier based strike aircraft. The scenarios show that even a small amount of leakage can have a significant effect on the number of missiles that get through to point defense. When a Surface Action Group can dilute the number of inbound missiles with decoys the attacker's advantage is greatly reduced so that the active point defense has a much better chance to defeat the inbound ASCMs.

2. Capabilities and Limitations

This is a high level, low resolution, flexible, deterministic model. It is meant to provide an analysis for force comparison that is as good as the performance data available. The model is not a reliable predictor of losses, but it will give rich insight as to how well one side matches up with the other. We limited our analysis of the missile salvos up to the point in which they would be engaged by point defense. The effects of jamming and chaff have been excluded for more emphasis on leakers and decoys, although it would not be difficult to incorporate them. The model discuses combat scenarios but is not intended to recommend specific tactics. The insight gained regarding vital ship characteristics is the central focus of the model and not battle outcomes.

B. RECOMMENDED DESTROYER CAPABILITIES AND CONCEPT OF OPERATIONS

1. Key Upgrades

The tactical aim is to launch a successful attack before the enemy can do so. But, the tactical plan must take account of a possible enemy first attack or exchange of ASCMs. Based on the analysis in this thesis we recommend three upgrades to current DDGs to prepare them for the mission of maintaining sea control against a Chinese Surface Action Group. The first upgrade to our DDGs is a TASM-like missile with a range of about 300 nautical miles. Currently, the U.S. is outranged by missiles like the YJ-62. This allows the Chinese SAG to attack without the potential for a U.S. counterattack. The second upgrade for our DDGs is to incorporate unmanned aerial systems to provide offensive and defensive AEW. The offensive scouting would be provided by the land-based maritime variant of Global Hawk. This would provide persistent offensive ISR for extended periods of time. In addition to Global Hawk we propose using the Fire Scout to provide local ISR and AEW for the SAG in a defensive role. The sensor data of both Global Hawk and Fire Scout fused with the Aegis System would greatly enhance offensive and defensive readiness. AEW provided by both systems would increase time to react to surprise attacks allowing for judicious use of decoys. Thirdly, decoys are crucial to diluting enemy raids. Fourthly, the allocation for missile quantities is also important. Each proposed DDG would have 10 TASM, 10 cells of ESSM, and 24 SM-2s, with the remaining cells available for SM-3s or TLAMs. These quantities have not undergone the scrutiny of sensitivity analysis but the need is evident that a USN SAG facing the PLA-N must have a strong element of these four capabilities.

2. Proposed Concept of Operations

A U.S. SAG of 4 upgraded DDGs would have 2 dedicated Global Hawks patrolling a 120 degree threat sector to locate and track an enemy SAG at a range of 80 to

100 nautical miles from the U.S. SAG. The tracking data would allow the U.S. to launch an attack using the new TASM's. On defense each DDG would carry 3 Fire Scouts rotating on station providing local ISR and AEW. Upon indication of an imminent attack each vessel would launch 3 decoys and use fused tracking information to engage the inbound salvo with SM-2s. The SM-2s will be used against ASCMs while saving the ESSM's for the potential threat of Harpy-like attacks. The offensive shortfalls are addressed with TASM and Global Hawk while the defensive shortfall is handled using Fire Scout and decoys.

C. PROPOSED MISSILE AND UNMANNED AERIAL SYSTEMS

1. Background

There are two ways a navy can deal with tactical shortfalls, build new platforms specifically suited to that mission, or update the systems on existing platforms. The U.S. Navy has depended on the large American industrial base and a virtual blank check to design and introduce new platforms. This is an expensive but suitable way of dealing with new threats. Unfortunately, this method results in a guessing game of calculating what the next conflict will present in the way of new threats, and even well planned platforms can be outpaced by the rate of change on the battlefield of the sea. The danger, therefore, is that navies will prepare to fight the conflict of tomorrow with the platforms of yesterday. The decision to upgrade older platforms with suitable new systems can be a faster more cost effective means to adapt to change. In 1991 the U.S. Navy did this with the USS Missouri, adding tomahawk missile canisters and upgrading the combat systems suite to use in the first Gulf War. Current warships have modernization plans that incorporate sequential development of onboard systems; the systems proposed are not currently operational. We are proposing a concept of operations that requires only three key systems upgrades to allow Arleigh Burke Destroyers to accomplish a sea control mission against a similarly composed force.

1. Tomahawk Anti Ship Missile (TASM)

The Tomahawk Anti Ship Missile was designed to carry a nuclear warhead, but as a result of the 1987 Intermediate-Range Nuclear Forces Treaty it was destroyed. Future variants of the tomahawk emerged as land attack missiles providing surface combatants with a potent deep-strike capability. The TASM non-nuclear variant never reemerged for maritime use. This oversight has left a capability gap in U.S. surface combatants ability to attack an enemy first, from outside his engagement range. We propose bringing back the TASM for use in surface warfare against a sea control navy. Unlike the Harpoon, the TASM can be stored and launched like a Tomahawk Land Attack variant but would provide a significant advantage in range and mission flexibility. By placing the TASM in the Mk-41 Vertical Launching System the ship also removes weight above the main deck that can be reallocated for point defense systems. Table 6 is a notional concept for a TASM or TASM-like missile for our proposed concept of operations.

Notional Tomahawk Anti Ship Missile (TASM)			
Dimensions:		**Performance:**	
Length	20 feet 6 inches	Max Range	300nm
Diameter	20 inches	Warhead	Conventional 1000 lbs
Wing Span	8 feet 9 inches	Speed	Subsonic- 250kt
Weight	3200 lbs	Guidance:	Inertial, Datalink, GPS

Table 6. Notional Tomahawk Anti Ship Missile (TASM) characteristics

2. Fire Scout

The Northrop Grumman MQ-8B Fire Scout is undergoing development for deployment on U.S. Navy Littoral Combat Ships. (Northrop Grumman 2008) We propose adapting this system for use with U.S. Arleigh Burke Destroyers. The system would be stationed at a suitable distance from the launching unit to provide point airborne early warning (AEW) in a threat sector using electro-optical (EO) and infrared (IR) scanning sensors. Additionally, Fire Scout could provide targeting data and laser designation of inbound missiles to the launching unit integrating with the Cooperative Engagement

Capability (CEC). This would allow a defending unit to engage attacking missiles at ranges that would maximize probability of hit against these threats. When seconds can decide the difference in a defending unit's ability to counter an attack a Fire Scout could provide the luxury time to make decisions and launch defensive SAM's. Fire Scout's AEW capacity will also allow adequate time to launch decoys which, as the analysis will show, can significantly change the result of an attack. For an individual unit to keep three Fire Scouts airborne they would most likely require three more spares and then an additional two in maintenance status. This would require each Destroyer to carry eight Fire Scouts. An SH-60B weighs approximately 21884 lbs. Eight Fire Scouts would weigh about 21600 lbs based on an individual weight of 2700 lbs. The potential for greater reaction time from increased AEW is arguably worth replacing one SH-60B.

Notional Fire Scout Unmanned Aerial System			
Dimensions:		**Performance:**	
Height	9 feet	Max Endurance	8 hours
Length	23 feet	Max Altitude	20,000 ft
Main Rotor Diameter	27 feet	Communications	Datalink, LOS
Gross Weight	2700 lb	Loiter Speed	115kt
Payload	130 lb	Sensors	EO, IR, Laser Desig

Table 7. Notional Fire Scout Unmanned Aerial System characteristics

3. Global Hawk, Broad Area Maritime Surveillance (BAMS)

Current satellite maritime surveillance capabilities cannot provide targeting data to surface combatants. This shortfall requires a dedicated ISR asset that can forward accurate targeting data for offensive attack. Northrop Grumman has developed the RQ-4B Block 20 Global Hawk for the U.S. Navy's Broad Area Maritime Surveillance requirement. (Northrop Grumman 2008) The system provides persistent high altitude long-endurance reconnaissance with high resolution. The sensors onboard the Global Hawk includes visible, electro-optical, infrared and synthetic aperture radar system (SAR) incorporated with a moving target indicator (MTI). Communications systems onboard would allow for reconnaissance information transmission to various data links, satellite, or LOS receivers. The operating altitude of this system helps minimize the threat of surface to air missiles launched from surface combatants. Our proposed concept of operations uses the Global Hawk to provide accurate location information of enemy surface combatants. This information allows for a surprise attack against an enemy surface action group using TASM. The Global Hawk system and the TASM provide the potential to defeat a sea control navy with a first strike before the enemy even knows they are being attacked.

Notional Global Hawk Maritime Unmanned Aerial System			
Dimensions:		**Performance:**	
Height	16 feet	Wide Area Search	40,000nm^2 per day
Length	48 feet	Max Endurance	33 hours
Wing Span	131 feet	Max Altitude	65,000 ft
Gross Weight	25,600 lb	Communications	Satellite, Datalink, LOS
Payload	2000 lb	Loiter Speed	300kt
		Sensors	EO, IR, MTI, SAR

Table 8. Notional Global Hawk Maritime Unmanned Aerial System characteristics

D. FUTURE RESEARCH

1. Timeline Analysis

Time is a critical factor in Surface Warfare. Additional time to engage salvos can provide greater depth of fire and more accurate tracking data. ISR information provided by UASs can alter the amount of time to respond to incoming salvos. A timeline analysis could provide another perspective on the number and stationing of UASs.

2. Range Dependent Lambda

In our analysis lambda remained constant for both forces. Since lambda is dependent upon the ships' Fire Control Systems ambiguity we could alter it to more accurately reflect different Fire Control Systems. A new SPY or active electronically steered array (AESA) radar would most likely change lambda. Engaging an inbound salvo at a greater range will increase lambda while engaging at a preferred range would decrease it. This analysis could shape firing doctrine and UAS stationing with more accurate missile tracking data from UASs.

3. Attacking Unmanned Aerial Systems

In our proposed Concept of Operations we recommended reserving ESSMs for a Harpy-like threat. This model could be applied as a one sided battle in which numerous UASs conduct attacks over an extended period of time.

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